NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

OAST SPACE THEME WORKSHOP

VOLUME IV

R & T BASE SUMMARY

A. APRIL 26, 1976, PRESENTATION

B. SUMMARY STATEMENT

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HELD AT THE

LANGLEY RESEARCH CENTER

APRIL 26-30, 1976

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Foreword

The attached material represents the working papers from the OAST Space Theme Workshop held at the Langley Research Center, April 26-30, 1976, and contains a quick-look analysis of the proceedings. The material is unedited and intended for further use by the participants of the workshop and the planning elements of NASA concerned with space mission research and technology. It should be understood that the data do not represent official plans or positions but are part of the process of evolving such plans and positions.

Nearly 100 of the Agency's top technologists and scientists joined with another 35 theme specialists to produce this working document - a document that provides a technical foundation, including research and technology base candidates, for each of the six space themes.

The material in this report is considered essential to the development of Center initiatives in support of these themes. Copies of the report will be made available to the Center Management Board and the individuals at the Centers responsible for the FY'78 program planning cycle. The timing of this planning activity has caused us to distribute this document in this unedited form. Thus, it possibly contains errors, hopefully, more of a typographical rather than a technological nature. Nonetheless, the information contained is of a high professional level, reflecting the efforts of the workshop participants and will be invaluable to the planning and successful execution of the Agency's near- and far-term advanced technology program.

Stanley R. Sadin
OAST Space Theme Workshop
Chairman
NASA Headquarters
Study, Analysis, & Planning Office
Office of Aeronautics and
Space Technology

R&T BASE THEME

DEFINITION

R&T BASE GENERALLY INCLUDES TASKS CULMINATING IN:

1. BASIC PHENOMENA OBSERVED AND REPORTED
2. THEORY FORMULATED TO DESCRIBE PHENOMENA
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL
4. PERTINENT FUNCTION OR PHENOMENA DEMONSTRATED
5. COMPONENT OR BREADBOARD TESTED IN LABORATORY

FOR PURPOSES OF THIS WORKSHOP

R&T THEME

OBJECTIVE

STRENGTHEN AND INCREASE THE R&T BASE THROUGH:

A. ADVOCACY AND SUPPORT OF RELEVANT ONGOING R&T BASE PROGRAM ELEMENTS AS AN INTEGRATED PART OF THE OTHER THEMES

B. IDENTIFICATION AND SUPPORT OF OTHER NEW AND PROMISING PROGRAM ELEMENTS AS CANDIDATES FOR THE RESULTANT FREED R&T BASE RESOURCES

R&T BASE THEME

APPROACH

1. IDENTIFY R&T BASE CANDIDATES FOR BOTH CATEGORY A (THEME-RELEVANT) AND CATEGORY B (NEW AND NONALINED) USING FORM NO. 1

   - FOR ONGOING WORK TO BE TRANSFERRED TO A THEME, INDICATE RTOP NUMBER AND ESTIMATED FY 78 FUNDING (NOA, $K) AS ITEM 3F OF FORM NO. 1
   - FOR NEW WORK, INDICATE ESTIMATED FY 78 FUNDING ONLY AS ITEM 3F OF FORM NO. 1

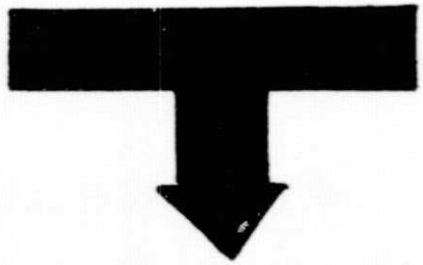
2. RANK ALL R&T BASE CANDIDATES IN PRIORITY ORDER USING R&T BASE COLUMN OF FORM II. CIRCLE RANKINGS IF CANDIDATES ARE ONGOING WORK IN CATEGORY A.

R&T BASE THEME

APPROACH (CONTINUED)

3. USE FORM VI (OR SIMILAR APPROACH) TO ASSESS CONTRIBUTION OF BOTH CATEGORY A & B CANDIDATES TO OAST GOALS

4. IDENTIFY OTHER NEW R&T BASE CANDIDATES NEEDED TO SUPPORT GOALS USING FORM IV



NOTE THAT CONTRIBUTION TO THE OAST GOALS WILL BE THE PRIMARY CRITERIA FOR RANKING OF NEW R&T BASE CANDIDATES. WRITEUPS FOR THESE CANDIDATES SHOULD SPECIFY THE EXPECTED CONTRIBUTION AND GOAL(S) THEY SUPPORT.

OAST SPACE TECHNOLOGY NEED FORM NO. 1

LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED
2. THEORY FORMULATED TO DESCRIBE PHENOMENA
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT
7. MODEL TESTED IN SPACE ENVIRONMENT

1. TITLE _____ NO. _____ THEME / W.G. / TASK

PAGE 1 OF ___

DATE / /

2. OBJECTIVE

3. NEED ANALYSIS

a) LEVEL NOW ☐, WILL BE LEVEL ☐ UNDER EXISTING PLANS.

b) REQUIRED ADVANCEMENT -- SHOULD BE TECHNOLOGY READY AT LEVEL ☐ FOR OPERATIONAL SYSTEM USE BY [DATE:]

c) RISK IN ACHIEVING ADVANCEMENT: HIGH ☐ MEDIUM ☐ LOW ☐

d) CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING ☐ OR ENHANCING: HIGH ☐ MEDIUM ☐ LOW ☐

e) TASKS NEEDED: STUDY ☐ ANALYSIS ☐ RESEARCH ☐ GRD TEST ☐ FLIGHT TEST [A] [B]

OTHER (Specify) ☐ _____ (Check one or more)

f) R&T BASE CANDIDATE 506-13-11, 4 400K

4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY

5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED

OAST SPACE TECHNOLOGY NEED PRIORITY ASSESSMENT

FORM II

(List in numerical order, 1 — Highest Priority)

WORKING GROUP _____

TECHNOLOGY NEED NO. / THEME	SPACE POWER 7	SPACE INDUST. 8	SETI 9	SOLAR SYS. EXPL. 10	GLOBAL SERVICE 11	ADV. TRANS. SYS. 12	ANT BASE 1	SUMMARY PRIORITY ASSESSMENT			
								WG	TT#	OAST DIV.	
							1				
							(2)				
							4				
							(3)				

THE OAST MISSION ...

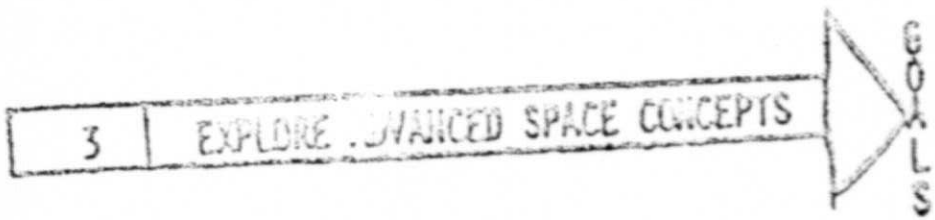
- TO PRODUCE AND ASSURE USE OF ADVANCED AEROSPACE TECHNOLOGY WHICH MEETS THE NATION'S NEEDS AND IS SAFE, RELIABLE AND COST-EFFECTIVE

THROUGH 3 MAJOR PROGRAM THRUSTS ...

- SUPPORT APPROVED MISSIONS
- ENABLE 1000-FOLD INCREASE IN EFFECTIVENESS OF FUTURE SPACE SYSTEMS
- EXPLORE ADVANCED CONCEPTS FOR NEW MISSION OPPORTUNITIES

- SPACE TRANSPORTATION
- EARTH OBSERVATIONS
- COMMUNICATIONS
- ENERGY SYSTEMS
- LUNAR/PLANETARY EXPLORATION
- ASTRONOMY/PHYSICS

- 10 X INFORMATION ACQUISITION (10^{16} B/YR)
- 10 X LARGER STRUCTURES (1 KM)
- 5 X POWER CAPACITY (200 W/KG, 100 WHR/KG)
- 1000 X INFORMATION MGMT (10^{16} B/YR)
- 1000 X PROPULSION EFFICIENCY (10^{5} KG/YR PLANETARY)
- 1/10TH TRANSPORTATION COST ($50/LB TO LEO)
- 1/10TH SPACECRAFT COST (8¢/MB)
- 1/2 MISSION SUPPORT COSTS
- 1/10TH SOFTWARE COSTS (2¢/MB)



- POWER PRODUCTION AND DISTRIBUTION
- NOVEL PROPULSION
- INFORMATION SYSTEMS
- STRUCTURES AND MATERIALS
- SPACE PROCESSING
- BASIC RESEARCH

FOR NATIONAL NEEDS ...

- TO STIMULATE AND SUPPORT THE ECONOMY
- TO PROVIDE ALTERNATE SOURCES OF ENERGY
- TO PRESERVE THE ENVIRONMENT
- TO ASSURE A VIABLE DEFENSE
- TO EFFICIENTLY MANAGE FOOD AND NATURAL RESOURCES
- TO PROTECT LIFE AND PROPERTY
- TO SATISFY MAN'S QUEST FOR NEW KNOWLEDGE

IV. R&T BASE SUMMARY

As part of the Space Theme Workshop, each working group viewed the R&T Base program to identify those tasks which either enabled or enhanced a theme and should be incorporated into that theme, and to identify new and promising R&T Base candidates which should be incorporated into the R&T Base to meet essential long-range space technology goals not addressed by the themes. The results of this assessment, based on the working group inputs, are summarized here to provide an initial overview of the potential impact of the themes on the R&T Base. As the themes evolve and specific R&T Base tasks are selected for support under a theme, this first-cut assessment will obviously be modified and refined. However, this early look at the possible R&T Base changes associated with the themes should permit more effective plannings of the themes and future R&T Base program elements.

R&T Base here was defined as any activity where end product did not involve aircraft or spacecraft demonstrations of components or systems. All technology tasks which were carried to State of the Art Level 5 on From 1 were thus considered.

The basic approach used for the R&T Base assessment is illustrated in figure VI.1. Recommended R&T Base changes were indicated in three categories. These were (1) theme-current R&T Base or ongoing tasks which should be included in a theme, (2) theme-increased R&T Base or new/increased tasks suggested for theme support, and (3) new R&T Base or high-payoff tasks recommended for fundings in the R&T Base. Current R&T Base resource renouts picked up by the themes will provide the opportunity for the initiation of new efforts in the R&T Base. The total R&T Base increase thus becomes the sum of theme-increased and theme-current R&T Base tasks funded by the themes.

The raw workings group inputs were collected to determine the overall changes proposed for the R&T Base. These inputs were then grouped into the three R&T Base categories and arranged in accordance with the working group priority rankings for each category. Figure IV.2 illustrates representative candidates in the theme - current category resulting from this process: These candidates, which generally reflect the reorientation or pursuit of an ongoing RTOP on specific theme objectives, primarily involved the development and ground testing of new-technology components and systems. Only high-priority tasks are shown in the figure; a total of 39 candidates were proposed in the theme-current category and are included in the appendix.

Figure IV. 4 summarizes the current ongoing R&T Base resource recommended for theme support. About $33M of FY 78 funding was included in the working group submissions. Note that no theme assignments are indicated since the theme teams have not yet selected their theme tasks and since most of the proposed candidates support several themes.

Figures IV. 5-6 illustrate corresponding working group inputs in the theme increased category. About 174 candidates were recommended by the working groups. The majority of these involved acceleration of current R&T Base programs to meet theme objectives; many of the related tasks culminated in flight tests to demonstrate technology readiness. Funding estimates here only include additional resources required for the incresed programs; roughly $67M fall in this category in FY 78.

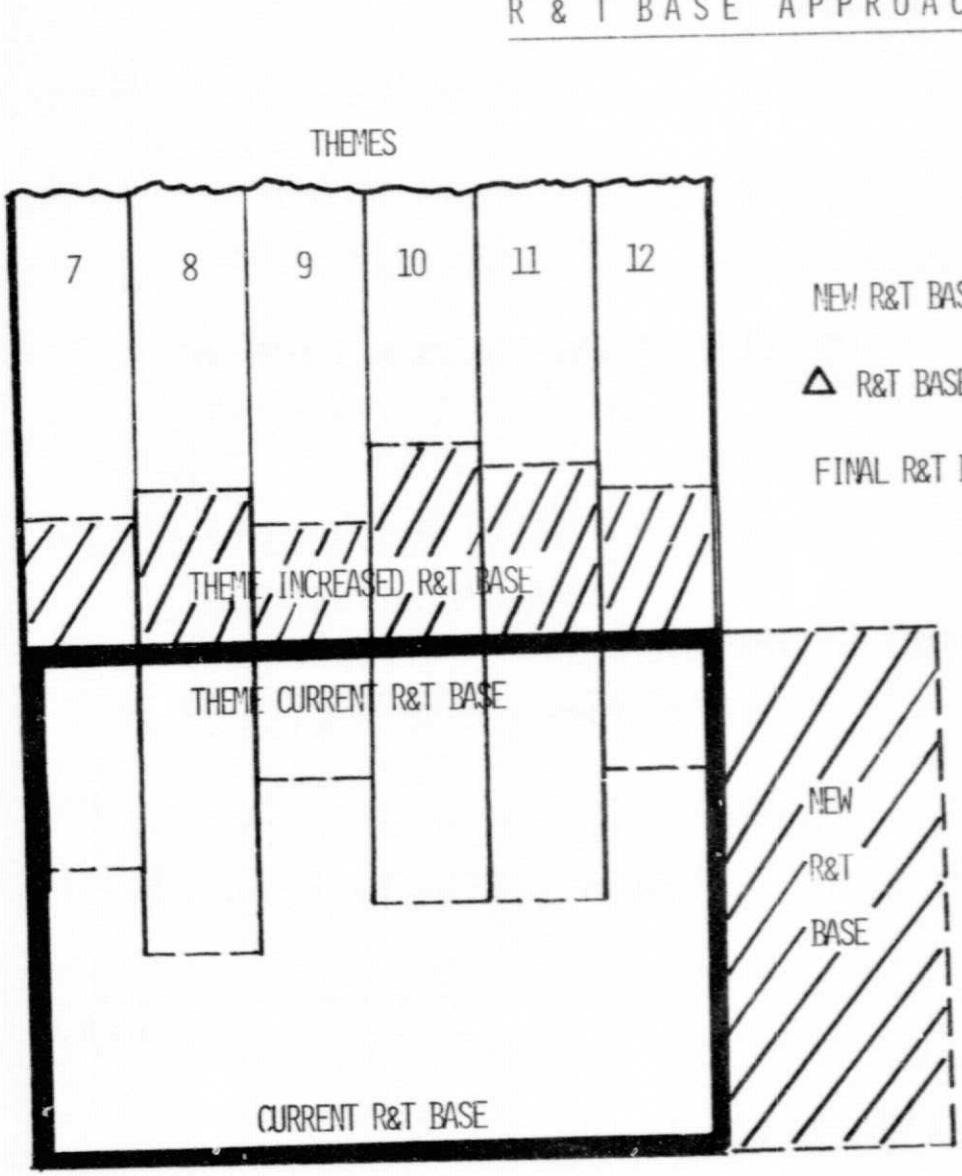
New R&T Base candidates which are independent of the themes are indicated in figures IV. 7-8. Because of the predominant workshop focus on the theme requirements, little or no time was available to address potential nonalined R&T Base candidates and only $>$ inputs were received in this category. These were photochemical production of hydrogen and oxygen for propellants and on thruster and ion beam research under propulsion and computational fluid dynamics, multi-engine base flow, and an energy conservative aerothermodynamics test facility under Aerothermodynamics. About $5M was requested to support these efforts in FY 78.

The maximum possible R&T Base impact of the theme effort is summarized in figure VI. 9. If all working group inputs were adopted, the effective R&T Base could increase by as much as $100M in FY 78. Since most of the R&T Base inputs were not identified until late in the workshop process, it was unfortunately impossible to review and prioritize this mass of inputs during the workshop. An attempt was made to screen the number of theme-relevant R&T Base candidates by obtaining feedback on the tasks which the theme teams would plan to incorporate into their programs. However, returns from this activity are not yet all in. A more definitive evaluation of the R&T Base candidates will be evaluated when this feedback is received from the theme teams.

In addition, other new R&T Base candidates will be identified in the coming months and assessed relative to their contribution to NASA's long range technology goals. This assessment will include the definition of new research areas which should be supported. One of these areas, discussed at the workshop, is applied mathematics illustrated in figure IV. 10.

A significant reorientation and increase in the R&T Base made possible by successful advocacy of the themes will hold the key to NASA's future in space.

R & T BASE APPROACH



NEW R&T BASE = THEME CURRENT R&T BASE

△ R&T BASE = (THEME INCREASED + NEW) R&T BASE

FINAL R&T BASE = (CURRENT + △) R&T BASE

WHERE

= CURRENT R&T BASE

= △ R&T BASE

+ = FINAL R&T BASE

Figure IV. 1

THEME CANDIDATES

CURRENT R&T BASE	FY 78, $K
NAVIGATION, GUIDANCE AND CONTROL	
o EXTENDED LIFE ATTITUDE CONTROL SYSTEM	450
COMMUNICATIONS AND DATA HANDLING	
o AUTONOMOUS, FAULT TOLERANT DATA HANDLING CONTROL AND COMMUNICATION SYSTEM	250
SENSORS	
o LASER HETERODYNE RADIOMETER	250
o LOW-COST ELECTRONIC SUBSYSTEM TECHNOLOGY	
o	

FIGURE IV. 2.

THEME CANDIDATES

CURRENT R&T BASE SUMMARY

WG \ TT		7 SPACE POWER	8 SPACE INDUST.	9 SETI	10 SOLAR SYS EXPL.	11 GLOBAL SERVICE SYSTEM	12 ADV. TRANS. SYS.	TOTAL $ K
E-1	NAVIGATION, GUIDANCE, AND CONTROL							3450
E-2	COMMUNICATIONS AND DATA HANDLING							5290
E-3	SENSORS							1610
E-4	SOFTWARE							0
P-1	PROPULSION							7525
P-2	POWER							5430
M-1	MATERIALS							4450
M-2	STRUCTURES/ DYNAMICS							1500
M-3	AEROTHERMODYNAMICS							3300
	TOTAL							32,555

FIGURE IV. 3

THEME CANDIDATES (CONT'D)

CURRENT R&T BASE	FY 78, $K
PROPULSION	
o HIGH SPECIFIC IMPULSE ELECTRIC PROPULSION FOR ORBITAL TRANSFER VEHICLE	250
o HYDROGEN-OXYGEN HIGH PERFORMANCE, REUSEABLE MAIN PROPULSION SYSTEM FOR ORBIT TRANSFER VEHICLES	1000
o STORAGE, SUPPLY AND TRANSFER OF CRYOGENIC FLUIDS IN SPACE	300
o	
POWER	
o LIGHTWEIGHT FUEL CELL	260
o LIGHTWEIGHT SOLAR ARRAY	320
o SILICON SOLAR CELL TECHNOLOGY	850
o MULTI-KW POWER DISTRIBUTION	70
o THERMOELECTRICS	265
o	
MATERIALS	
o THERMAL PROTECTION SYSTEMS	500
o MIN K REFRIGERATORS	200
o ADVANCED LUBRICANTS	100
o PLANETARY PROBES	400
o HIGH STRENGTH ALLOYS AND COMPOSITES	400
o	

FIGURE IV. 2. CONTINUED

THEME CANDIDATES (CONT'D)

CURRENT R&T BASE	FY 78, $K
STRUCTURES/DYNAMICS	
o ADVANCED VEHICLE STRUCTURES	800
o PAYLOAD DYNAMICS AND ACOUSTICS	500
o DEPLOYABLE LASER MIRROR	200
o	
AEROTHERMODYNAMICS	
o ADVANCED STS VERIFICATION AEROTHERMODYNAMICS BY FLIGHT TEST	1000
o ATMOSPHERIC PROBES/EARTH RETURN-HEATING AND FLOW FIELD DEFINITION	800
o ADVANCED STS CONFIGURATION CHARACTERIZATION	300
o	

FIGURE IV. 2. CONCLUDED

THEME CANDIDATES

NEW R&T BASE

	FY 78, $K
AEROTHERMODYNAMICS	
o INCREASE COMPUTATIONAL FLUID DYNAMICS CAPABILITY	750
o CALCULATE MULTI-ENGINE BASE FLOW	200
o DEVELOPMENT OF ENERGY-CONSERVATIVE AEROTHERMODYNAMICS TEST FACILITY	2200
PROPULSION	
o PHOTOCHEMICAL PRODUCTION OF HYDROGEN AND OXYGEN FOR PROPELLANTS	150
o ION THRUSTER BASELINE R&T	500
o ION BEAM APPLICATION RESEARCH	500
o ION BEAM APPLICATION TO SPACE MANUFACTURING	500

FIGURE IV. 6.

THEME CANDIDATES

INCREASED R&T BASE	FY 78, $K
NAVIGATION, GUIDANCE, AND CONTROL	
o ATTITUDE, FIGURE, AND STABILIZATION CONTROL OF LARGE SPACE STRUCTURES	900
o PRECISION POINTING AND TRACKING SYSTEMS FOR NON-POINT-SOURCE TARGETS	450
o PRECISION POINTING OF SPACECRAFT AND INSTRUMENTS AT INERTIAL TARGETS	2725
o AUTONOMOUS OPERATING AND MISSION MODIFICATION	150
o ROBOTIES AND TELEOPERATORS FOR SPACECRAFT ASSEMBLY AND MAINTENANCE	1300
o	
COMMUNICATIONS AND DATA HANDLING	
o END-TO-END DATA MANAGEMENT	600
o DATA SET SELECTION	300
o MODULAR DATA SYSTEM ARCHITECTURE	65
o PATTERN RECOGNITION ANALYZER	1400
o HIGH-RATE DATA PROCESSOR	400
o	

FIGURE IV. 4.

THEME CANDIDATES (CONT'D)

INCREASED R&T BASE	FY 78, $K
SENSORS	
o UV/VISIBLE/IR IMAGING ARRAYS	200
o MICROWAVE SOUNDING RADIOMETERS	300
o HIGH-POWER LASERS/LIDAR TECHNOLOGY	120
o PLANETARY SURFACE CHEMISTRY ANALYSIS BY ALPHA PARTICLES GAMMA-RAY, AND X-RAY SPECTR.	150
o MULTI-FREQUENCY MICROWAVE IMAGING RADIOMETER	200
o	
SOFTWARE	
o MULTIDIMENSIONAL DATA SYSTEMS	300
o PATTERN RECOGNITION	500
o SOFTWARE FOR SYSTEM INTEGRITY	300
o PROGRAMMING LANGUAGE & TRANSLATORS	700
o PROGRAMMING METHODOLOGY	400
o	

FIGURE IV. 4. CONTINUED

THEME CANDIDATES (CONT'D)

INCREASED R&T BASE	FY 78, $K
PROPULSION	
o MPD THRUSTER SYSTEM TECHNOLOGY READINESS	600
o SOLID PROPULSION ADVANCED TECHNOLOGY MOTOR	850
o HIGH SPECIFIC IMPULSE ION THRUSTER FOR ON-ORBIT OPERATIONS	250
o AIR AUGMENT EARTH-TO-ORBIT CHEMICAL ROCKET ENGINES	50
POWER	
o OASIS STUDY	2000
o SEP ARRAY	500
o PHOTOVOLTAIC ELECTROLYSIS FOR FUEL CELL	500
o AUTOMATED POWER SYSTEMS MANAGEMENT	215
o ENVIRONMENTAL CHARGING OF SURFACES	225
o	
MATERIALS	
o MATERIALS FOR ADVANCED PROPULSION	300
o POWER GENERATION MATERIALS/PROCESSES	400
o POWER STORAGE & TRANSMISSION MATERIALS	100
o DEVELOPMENT OF FABRICATION TECHNIQUES FOR SPACE-ERECTABLE STRUCTURES	500
o LARGE ANTENNA STRUCTURES	200
o	

FIGURE IV. 4. CONTINUED

THEME CANDIDATES (CONT'D)

INCREASED R&T BASE	FY 78, $K
STRUCTURES/DYNAMICS	
o SPACE DEPLOYED LARGE STRUCTURES	600
o SPACE ASSEMBLED LARGE STRUCTURES	700
o LAUNCH VEHICLE LOADS ANALYSIS OPTIMIZATION	300
o DAMAGE TOLERANCE	700
o SOLAR SAIL STRUCTURE	300
o	
AEROTHERMODYNAMICS	
o ADVANCED STS BASIC FLOW PHENOMENA	100
o ATMOSPHERIC PROBES/EARTH RETURN-DEVELOPMENT OF STABLE CONFIGURATION	500
o	

FIGURE IV. 4. CONCLUDED

THEME CANDIDATES

INCREASED R&T BASE SUMMARY

WG \ TT		7 SPACE POWER	8 SPACE INDUST.	9 SETI	10 SOLAR SYS EXPL.	11 GLOBAL SERVICE SYSTEM	12 ADV. TRANS. SYS.	TOTAL $ K
E-1	NAVIGATION, GUIDANCE, AND CONTROL							9,325
E-2	COMMUNICATIONS AND DATA HANDLING							13,125
E-3	SENSORS							5,590
E-4	SOFTWARE							4,930
P-1	PROPULSION							9,275
P-2	POWER							11,230
M-1	MATERIALS							10,400
M-2	STRUCTURES/ DYNAMICS							2,600
M-3	AEROTHERMODYNAMICS							820
	TOTAL							67,305

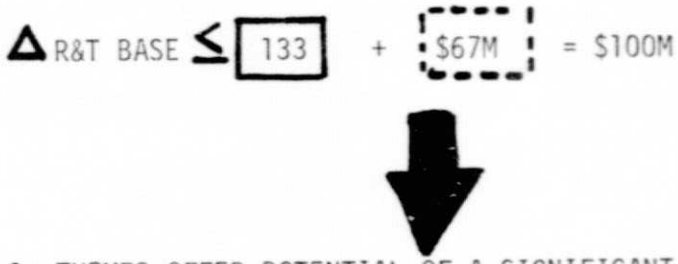
FIGURE IV. 5

NEW CANDIDATES

WG	R&T BASE	TOTAL $ K
E-1	NAVIGATION, GUIDANCE, AND CONTROL	0
E-2	COMMUNICATIONS AND DATA HANDLING	0
E-3	SENSORS	0
E-4	SOFTWARE	0
P-1	PROPULSION	1,650
P-2	POWER	0
M-1	MATERIALS	0
M-2	STRUCTURES/DYNAMICS	0
M-3	AEROTHERMODYNAMICS	3,150
	TOTAL	5,800

FIGURE IV. 7

ΔR&T BASE



- THEMES OFFER POTENTIAL OF A SIGNIFICANT INCREASE IN THE EFFECTIVE R&T BASE
- ADDITIONAL WORK IS REQUIRED TO PRIORITIZE R&T BASE TASKS IDENTIFIED AT THE WORKSHOP

Figure IV. 9

APPLIED MATHEMATICS

AREA	REPRESENTATIVE SUBJECTS	REPRESENTATIVE TASKS	POTENTIAL IMPROVEMENT
MATHEMATICAL MODELING	SOLUTION OF DIFF. EQUATIONS PARAMETER ESTIMATION NON-LINEAR EQUATIONS NUMERICAL ANALYSIS	VEHICLE DYNAMICS CRACK AND DAMAGE PROPOGATION AERODYNAMICS AND ATMOSPHERES SIMULATION	HUMAN TIME 5X COMPUTER TIME 5X ENABLE NEW SOLUTIONS
ESIGN	OPTIMIZATION MATHEMATICAL PROGRAMING GRAPHICS	CONTROL SYSTEM DESIGN ANTENNA CONFIGURATIONS SOLAR SAIL STRUCTURES DECELERATOR DESIGN	HUMAN TIME 10X COMPUTER TIME 5X MORE DETAILED DESIGN
DATA ANALYSIS	APPLIED STATISTICS PATTERN RECOGNITION APPROXIMATION THEORY	SIGNAL ANALYSIS (SETI) MULTISPECTRAL ANALYSIS SOIL SAMPLE ANALYSIS	COMPUTER TIME 10X COMPUTER STORAGE 10X ENABLE NEW SOLUTIONS
CONTROL	CONTROL THEORY DECISION THEORY ARTIFICIAL INTELLIGENCE	AUTONOMOUS NGC THERMAL CONTROL SPACE HABITATS PRECISION POINTING STABIL. OF LARGE STRUCTURES	COMPUTER TIME 10X COMPUTER STORAGE 10X ENABLE AUTONOMOUS CONTROL
COMPUTATIONAL EFFICIENCY	NUMERICAL METHODS DATA STORAGE AND RETRIEVAL DATA COMPRESSION SYMBOLIC MANIPULATION	DATA MANAGEMENT MOST COMPUTATIONAL TASKS	COMPUTER TIME 10X COMPUTER STORAGE 10X

Figure IV. 10